

Direct Volume-Controlling Device (DVCD) For Reciprocating Positive-Displacement Pumps

This application claims the benefit under 35 USC §119(e) to U.S. Serial No. 13/827,136, filed 03/04/2013, which claims the benefit under 35 USC §119(e) to U.S. Serial No. 61/639,524, filed 04/27/12, both of which are incorporated by reference herein in their entirety.

Field of Invention.

The present invention relates to pumps and fluid injection systems.

Background.

Positive displacement pumps are used to deliver or “dose” a predictable, precise amount of fluid in a repeatable fashion. Commonly, positive displacement pumps use the reciprocating motion of a solid object such as a plunger, piston, or diaphragm to withdraw fluid from a continuous source during a suction stroke, then to displace the withdrawn fluid during a discharge stroke. In such reciprocating positive displacement pumps, it is typical to control the flow of fluid such that the withdrawn portion of fluid does not return to its source during the discharge cycle, but is prevented from doing so by a suction check valve that allows flow in only one direction, towards the pump. It is also typical that a discharge check valve be present to direct flow away from the pump and towards the intended recipient process and to prevent any fluid from returning to the pump from the recipient process during its operation.

Brief Description of Drawings

Figure 1 illustrates a positive displacement pump.

Figure 2 illustrates a Direct Volume Controlling Device (DVCD) position on the pump of Figure 1.

Figure 3 is a perspective view of one embodiment of a DVCD.

Figure 4 is an exploded view of the DVCD illustrated in Figure 1.

Figure 5 is a cross-sectional view of the DVCD illustrated in Figure 1 in a first position.

Figure 6 is a cross-sectional view of the DVCD illustrated in Figure 1 in a second position.

Figure 7 is a cross-sectional view of the DVCD illustrated in Figure 1 in a third position.

Figure 8 is a cross-sectional view of the DVCD illustrated in Figure 1 in a fourth position.

Figure 9 is a cross-sectional view of the DVCD illustrated in Figure 1 in a fifth position.

Figure 10 is a cross-sectional view of the DVCD illustrated in Figure 1 in a sixth position.

Figure 11 is a perspective view of a second DVCD embodiment.

Figure 12 is a cross-sectional view of the DVCD illustrated in Figure 11.

Figure 13 is a perspective view of a third DVCD embodiment.

Figure 14 is an exploded view of the DVCD embodiment shown in Figure 13.

Figure 15 is a cross-sectional view of the DVCD illustrated in Figure 13.

Figure 16 is a cross-sectional view of the DVCD illustrated in Figure 13 showing the fluid path.

Figure 17 is a cross-sectional view of a fourth DVCD embodiment.

Figure 18 is an enlarged view of the DVCD seen in Figure 17.

Figure 19 is a view similar to Figure 18, but illustrating a different plunger position.

Figure 20 is an end view of the DVCD/pump unit showing the section line used in Figure 21.

Figure 21 is a cut-way view of a modification to the DVCD embodiment seen in Figure 17.

Detailed Description of Selected Embodiments

Figure 1 illustrates one type of conventional positive displacement pump assembly, with a “driver” portion 100 and a pump “head” assembly 105 (also referred to as a “wetted end” or a “fluid end,” among other terminologies). The head assembly 105 is the part of the pump assembly that comes into contact with the fluid to be pumped. Naturally, the pump head assembly 105 illustrated is only one of a multitude of pump head designs that are employed in positive displacement pump systems. The driver portion 100 of the pump assembly is also only one of several designs which are employed in reciprocating positive displacement pumps. The driver could be, and often is, energized by pressurized gas (pneumatic), in which a piston reciprocates over time driven by alternating gas pressure (see for example the pump in US Patent No. 8,087,345, which is incorporated by reference herein). The driver could also be electrical, for example where a rotating motor utilizes mechanical means to convert that rotational motion to reciprocating motion. The driver could also be powered by a hydraulic fluid or any other energy source, in which that energy is ultimately a repeatable, alternating, reciprocating motion. The driver type shown in Figure 1 is pneumatic, for illustrative purposes only and many different types of convention or future developed drivers could be employed with the present invention.

Many embodiments of the present invention relate to controlling the flow rate or output of the fluid from the pump at the head portion of the pump assembly. In Figure 1, a plunger-type pump head 105 is depicted. In this conventional type of pump head, a driver acts upon a plunger in a linear reciprocating (back and forth) motion. The plunger is connected to the pump head utilizing a seal, which is designed to create a barrier between the environment and a chamber inside the head, isolating the chamber hermetically. The seal

allows the plunger to move slidably up and down in a chamber while maintaining a tight hermetic seal. As the plunger partially, but not completely, withdraws from the chamber inside the head, it creates suction (negative pressure) inside the chamber. Figure 1 also shows a suction check valve 106 attached to head portion 105. When check valve 106 is attached to a fluid source, fluid is drawn into the pumping chamber, filling the expanding space created by the withdrawing plunger. At a certain point, the plunger (by virtue of the reciprocating motion of the driver) ceases to withdraw and begins to descend back into the chamber. This action raises the pressure in the chamber, causing suction check valve 106 to close, and forcing the fluid to exit the chamber via a discharge check valve 107.

Several other types of positive displacement pump heads utilize various means of alternately creating negative and then positive pressure to intake and then discharge fluid in a controlled manner. In each of these pump head designs, at least one suction check valve and at least one discharge check valve are employed. For example, a second, very common type of pump head, not illustrated in the drawings, is referred to as a “diaphragm” type pump head. This pump head utilizes hydraulic fluid pressure, generated by reciprocating motion of a plunger, to act on one side of a diaphragm or a sandwich of diaphragms. In this type of head design, the fluid being pumped is acted upon by the opposite side of the diaphragm or diaphragm assembly. Other types of pump heads utilize alternative means of controlling, actuating, and pumping fluid, e.g., a bellows type pump head. All such pump heads, and potentially many other conventional and future developed pump heads, may be used in conjunction with the present invention.

Many embodiments of the present invention relate to controlling the amount of fluid that is discharged during the discharge cycle of any reciprocating pump, regardless of type, including where the pump head utilizes a discharge check valve and mechanically changes the internal volume of a chamber via reciprocating motion. Figure 2 depicts a pump assembly similar to Figure 1, but with the substitution of the discharge check valve 107 with one embodiment of the present invention, the Direct Volume Controlling Device (DVCD) 1.

Figure 3 better illustrates the external features of this embodiment of the DVCD 1 with it removed from the pump assembly. Figure 3 shows DVCD 1's housing 2, end cap 7, inlet 3, outlet 4, and a volume adjustment mechanism, which in the illustrated embodiment is control knob 35, including graduated indicator ring 36. Inlet 3 may include any conventional means for connecting to a pump head, for example, a threaded nipple 70 through which inlet 3 is formed. Similarly, outlet 4 may have a threaded surface or other connection means

allowing for attachment to a suitable pipe or tubing from the DVCD 1 to the process requiring fluid to be metered or pumped to it. Various means to connect DVCD 1 to the pump head and to the process are contemplated by the present invention. For example, the threaded portion at the bottom could be a tapered pipe thread or any other conventional or future developed mechanical means. In the preferred embodiment, attachment to the pump head is via a straight thread with a sealing means (e.g., an o-ring type seal positioned in seal groove 39) to seal against the pump head. The threaded portion proximate to outlet 4 could be any type of thread to correspond with the process for which it is to be used, or it could also be made to accept low pressure “swaged” tubing fittings, or medium or high pressure “coned and threaded” connections, for example. The internal components of DVCD 1 may be better understood by viewing Figure 4 (an exploded view of the DVCD 1) and Figure 5 (a cutaway view of an assembled DVCD 1). Figure 5 illustrates how threads 38 on the upper end of housing 2 will engage mating threads on end cap 7 with o-ring 8 forming a seal between these elements. Formed within the housing is internal chamber 5, which will include the major components of a seat mechanism or means (in this embodiment adjustable seat 16), one-way valve 45, an accumulator 10, and a positioning mechanism or means 20 for allowing the position of accumulator 10 to be adjusted as described in more detail below. The lower end of internal chamber 5 includes tapered sidewalls 9 to facilitate a sealing engagement with accumulator 10. In certain embodiments, internal chamber 5 includes a volume which may be referred to as the accumulator chamber.

The illustrated embodiment of adjustable seat 16 is best seen in Figure 4. This embodiment includes the circular base 60 with seal ring groove 64 and upright section 61 with elliptical opening 62 and cam pins 63 (e.g., upper cam pin 63B and lower cam pin 63A, the function of which is explained below). Figure 5 illustrates how spacer 17 slides within circular base 60 and quad ring seal 18 is positioned within groove 64 to form a seal with the internal sidewalls of internal housing chamber 5. Figure 4 also shows how this embodiment of accumulator 10 includes a main body 14, a smaller diameter upper section 41, a seal groove 42, and a lower open passage 44 (seen in Figure 5). Viewing Figure 5, it is seen how this embodiment positions quad seal ring 11 and backup seal ring 12 in seal groove 42. Figure 5 also shows how passage 44 communicates with an internal cavity 15 which is formed in accumulator body 14 and how smaller diameter upper section 41 slides into spacer 17 within circular base 60 of adjustable seat 16.

The illustrated embodiments of accumulator 10 further include a one-way valve 45

positioned within the accumulator's internal cavity 15. In these embodiments, the one-way valve is shown as being a poppet-type valve including poppet 46, pressure differential spring 47, spring retainer 48, and o-ring 49. The poppet 46 includes a series of side apertures 50 and while hidden from view, an open top section such that fluid entering the poppet side apertures may exit through the open top section. It can further be seen that spring 47 biases the end of poppet 46 having o-ring 49 against lower part of accumulator internal cavity 15. While the illustrated embodiments show a one-way valve formed of a poppet assembly, many different conventional or future developed one-way valves may be utilized, as nonlimiting examples, various regulators (e.g., back-pressure regulators), solenoid valves, or shuttle valves.

Figure 4 best illustrates the individual components of one embodiment of positioning mechanism 20, which affects the position of adjustable seat 16 and ultimately accumulator 10 as explained in greater detail below. The main components of positioning mechanism 20 include shaft 21, cam members 22A and 22B, and knob 23 which acts as a control surface or gripping surface for applying torque to shaft 24. Other components of positioning mechanism 20 include spiral rings 29, washers 28, backup rings 27, o-rings 26, graduated scale ring 24, fixing pins 25, and securing screw 30. Shaft 24 will be positioned extending through elliptical opening 62 of adjustable seat 16 (better seen in Figures 5 and 6) and fixing pins 25 will fix cam members 22 against rotation on shaft 21 with the cam surfaces 33 (Figure 5) of each cam member being oriented approximately opposite one another. Viewing Figure 5, it can be understood how rotation of cam members 22 causes the cam surfaces 33 to ride upon the cam pins 63 formed on adjustable seat 16. For example in Figure 5, the illustrated cam surface 33 of cam member 22A urges lower cam pin 63A downward relative to DVCD housing 2 (i.e., since shaft 21 is fixed vertically relative to housing 2 by extending through the sides of the housing) and thereby urges adjustable seat 16 downward within housing 2. Although not specifically shown in the drawings, it may also be understood how cam member 22B acting on upper cam pin 63B will urge adjustable seat 16 upwards. The adjustment of knob 23 rotates shaft 21, cam members 22, and thereby moves adjustable seat 16 while scale ring 24 provides a visual indication of the degree of cam member movement. In the illustrated embodiment, the graduation lines on scale ring 24 are calibrated to a linear distance adjustable seat 16 moves upon rotation of knob 23. Through this mechanism, the cam members 22 act to precisely control the upward and downward movement of adjustable seat 16 in the internal housing chamber.

Although several structural components are positioned within housing internal

chamber 5, there is nevertheless a fluid path around these components from inlet 3 to outlet 4. Once fluid pressure at inlet 3 causes one-way valve 45 to open and fluid is allowed to flow through accumulator 10, a fluid path exists through poppet 46, through adjustable seat circular base 64, around positioning mechanism 20, and through outlet 4.

Operation of Illustrated Embodiments.

When employed in a positive displacement pump system, DVCD 1 may be connected to the pump head assembly by threads or other mechanical means located on the lower exterior of the housing 2 as suggested in Figure 2. Referring to Figure 5, the adjustable seat 16 is shown in the closed or lower position and completely constrains the motion of the accumulator 10 such that it remains tightly positioned against tapered internal sidewalls 9 of housing 2. In this position, it can be understood that when the pump head begins the discharge or pressurizing portion of its cycle, fluid becomes pressurized in the inlet 3 of the DVCD assembly. In the illustrated embodiments, fluid enters from the bottom through inlet 3 and encounters the bottom portion of accumulator 10, which cannot move in response to the fluid pressure being exerted upon it because of adjustable seat 16 being in the fully lowered position. The pressurized fluid acts against poppet 46, which although biased closed by spring 47, will open if fluid pressure is sufficient to overcome the force of spring 47.

Figure 6 illustrates poppet 46 moving to the open position under fluid pressure. The actuation of poppet 46 allows fluid to pass through the resulting gap between the interior walls of accumulator internal cavity 15 and poppet o-ring 49, then through the poppet side apertures or ports 50 and through the open top section of poppet 46. Once fluid moves through poppet 46, it freely passes through the interior of the adjustable seat 16, positioning mechanism 20, and exits the DVCD assembly through outlet 4. It will be understood that once DVCD 1 is running in steady-state (e.g., the interior is filled with the fluid being pumped), then all fluid moved during the discharge cycle of the pump must flow into DVCD 1 and an equivalent mass of fluid (assuming a generally incompressible fluid) must exit outlet 4.

Figure 7 is illustrated with pressure removed from the interior of DVCD 1 for purposes of clarity. It can be seen that the cam members 22 (which are attached to one another and therefore move as a single unit), have been rotated about 145 degrees counterclockwise, which also actuates the adjustable seat 16, causing it to move upwards and thereby creating a gap between the adjustable seat 16 and the accumulator 10. Because no

pressure is acting on accumulator 10, it remains positioned against the bottom sidewalls 9 of internal chamber 5. Likewise, poppet 46 remains seated against the bottom of accumulator internal cavity 15, due to the force applied against it by spring 47. With the adjustable seat 16 in this “midway” position, as the pump head begins to apply pressure during a discharge portion of its cycle, fluid begins to apply pressure upon and push through the interior of the DVCD inlet 3, exerting pressure on the accumulator 10 and the poppet 46 simultaneously. The poppet 46 is still held in its lower position against the seat portion of the accumulator 10 by spring 47. However, the fluid movement actuates the accumulator 10, causing it to move slidably upwards until it contacts the lower edge of the adjustable seat 16 (specifically spacer 17) as suggested in Figure 8. The poppet 46, which had continued to be seated as accumulator 10 moved to its second position, now becomes the only path available to the pressurized fluid, and therefore the poppet 46 actuates upwards as the fluid pressure overcomes the force of spring 47, again allowing fluid to pass as previously described. In this operation sequence, it can be understood how a volume of fluid V_1 discharged from the pump head is utilized or “borrowed” to hold the accumulator 10 against the adjustable seat 16 prior to actuation of the poppet 46. Once this volume of fluid enters DVCD 1, any additional fluid will actuate poppet 46 and flow through the poppet 46 and contribute to the fluid moved out of outlet 4 until the end of the discharge portion of the reciprocating pump cycle. As previously described, at the end of the discharge portion of the cycle, fluid momentarily stops flowing. At this moment, the pump head again begins its replenishment or suction portion of its cycle. But unlike as described when accumulator 10 was fully constrained, now, before fluid can begin to flow into the pump through the suction check valve assembly 106 (see Figure 2), the accumulator 10 and the poppet 46 first both react to the instantaneous vacuum that marks the beginning of the replenishment by moving slidably downwards to their seated positions. As they move downwards together, they displace a volume of fluid, the same amount (V_1) as was used to originally actuate them, backwards into the pump head assembly. During this portion of the cycle, it can be understood that no new fluid will enter the pump head, rather only fluid previously used to displace the accumulator 10. Both accumulator 10 and poppet 46 now return to their downwards and fully seated positions, as previously shown in Figure 7. At this moment, no more fluid may enter the pump head assembly from DVCD 1. Now, for the remainder of the replenishment or suction portion of the pump cycle, new fluid will enter the pump head through the suction check valve assembly 106, similar to the operation of the prior art device of Figure 1.

Through this description of Figures 7 and 8, it can be understood that, overall, less fluid was discharged through DVCD 1 during the described cycle than when the accumulator 10 was constrained in the full downward position (i.e., as in Figure 5) throughout the entire cycle. Once the accumulator 10 is not fully constrained, an amount of fluid is not replenished during the suction cycle, as the accumulator travels between its seated and unseated positions, and then returns back to its original position. In essence, the pump displaces a combination of fluid and solid, with the difference being the volume of fluid V_1 required to displace the accumulator 10, which is displaced over the precise distance allowed by the adjustable seat 16. The pump head is therefore not allowed to replenish that volume of fluid during the suction cycle. The pump's overall output was reduced by the volume displaced.

Figures 9 and 10 illustrate the cam members having been rotated a further 180 degrees counterclockwise, to their maximum rotational position. At this point, both cam members are prevented from moving further because a curved face notch 34 in the cam surfaces have engaged cam pins 63. As previously described, this further rotation of cam members 22 further slidably actuates the adjustable seat 16, causing it to move further upwards and thereby creating a larger gap between the adjustable seat 16 and the accumulator 10. All movements and actions are as previously described in reference to Figures 7 and 8, except that now the accumulator 10 is allowed to move a maximum distance and saves a larger volume V_2 from moving through outlet 4. From the above description, it will be understood that cam members 22 can be rotated to any position, causing adjustable seat 16 to range from fully lowered to fully raised, and that accumulator 10 will therefore displace an adjustable amount of fluid as it travels in both directions in response to pressure or vacuum created by the cycles of the pump head assembly.

Those skilled in the art will readily understand that the dimensions of DVCD 1, including the diameter of the housing internal chamber 5 and accumulator 10, and the amount of travel allowed by varying the diameter of the cam member 22 at their largest and smallest dimensions, and possibly other parameters, will determine the maximum amount of fluid that will be subtractable from the output of a pump to which DVCD 1 is connected. It is preferred that DVCD 1 have a fully seated or closed position, in which the pump head has maximum output and efficiency, and then a variable amount of fluid which can be subtracted from the pump output by adjusting the accumulator position within DVCD 1.

Although certain specific embodiments of DVCD 1 have been described in detail in Figures 1-10, the present invention includes many alternative embodiments. As one example,

an alternative positioning mechanism 20 is shown in Figures 11 and 12. In this embodiment as best seen in Figure 12, adjustable seat 16A includes an elongated stem 85 which has central passage 86 and threaded section 87. Threaded section 87 will engage corresponding threads formed on the interior surface of housing chamber 5 as suggested in Figure 12. Thus, rotation of adjustable seat 16A counterclockwise or clockwise will result in it moving upward or downward within housing 2A and thereby adjusting the space accumulator 10 has to move within housing chamber 5. One manner of applying torque to rotate adjustable seat 16A is to form seat access windows 52 in housing 2A (Figure 11) and seat torque holes 53 in adjustable seat 16A. A rod or other tool will access torque holes 53 through access windows 52 and allow adjustable seat 16A to be rotated. It will be understood that this embodiment differs from previous embodiment by allowing the adjustable seat to be directly rotated around the axis of the device rather than indirectly using cam members 22 as previously described.

Figure 12 also illustrates how o-ring seal 27 with backup seal 26 will prevent fluid from migrating around the top end of adjustable seat 16A and escaping through access window 52. Likewise, wiper seal 55 prevents fluid from migrating around the bottom end of adjustable seat 16A and escaping through access window 52. The fluid path in Figure 12 may be visualized when fluid pressure at inlet 3 overcomes poppet spring 47. Fluid flows through poppet 46 as previously described, but then may flow directly into stem passage 86 and then exit outlet 4. The housing 2A also differs from the earlier embodiment by having a smaller lower section threaded onto a larger upper section (see overlapping threads 56). As in the earlier embodiment, an o-ring 8 is positioned to effect a seal between the upper and lower sections of housing 2A.

A still further embodiment of the DVCD device is seen in Figures 13 to 16. Figure 13 illustrates how this embodiment has a volume control knob 223 positioned opposite inlet 203 while the outlet 204 is formed on the side of housing 2B. Figures 14 and 15 better illustrate how this embodiment of DVCD forms the adjustable seat with a stem or shaft 215 with inverted cup structure 225 on the lower end and the upper end being connected to control knob 223. Shaft 215 passes through retaining nut 222 and threadedly engages nut 222, while nut 222 in turn threadedly engages the top section of housing 2B. A u-cup or unidirectional seal 219 is positioned between balanced shaft 215 and nut 222; an o-ring with backup seal 217 is positioned between shaft 215 and the internal sidewall of housing 2B; and a further a u-cup or unidirectional seal 216 is positioned at the point where shaft 215 enters the open cavity of housing 2B containing inverted cup 225 of the adjustable seat.

Shaft 215 is considered a “balanced shaft” in the sense that it has pressure bearing surfaces in multiple directions to neutralize pressure induced forces tending to bind its threaded surfaces. Figure 15 illustrates balance shoulder 220 on shaft 215 which is subject to the DVCD’s internal fluid pressure via shaft central passage 221 and shaft side passages 224. Thus, when pressure acting on the bottom of accumulator 210 will tend to exert an upward force upon and potentially bind the threads on shaft 215, pressure on balance shoulders 220 will tend to exert a counter acting force, thereby reducing the tendency for the threads to bind. Figure 15 also illustrates the relief passage 227 which will bleed-off any fluid pressure escaping past seal 216 and which would otherwise tend to act adversely on the lower side of balance shoulder 220.

The accumulator 210 is similar to that of other embodiments in that it includes a one-way valve formed of poppet 246 being biased against internal sidewalls of the accumulator by spring 247. Similarly, accumulator 210 have a wiper seal 255 and o-ring 240 engaging the tapered internal sidewalls at the lower section of housing 2B in order to form a seal when accumulator 210 is in its lower-most position.

Figure 16 illustrates the situation where knob 223 has been rotated in order to raise the adjustable seat and its inverted cup 225 in order to allow accumulator 210 to move up from the bottom of the housing internal chamber upon the application of fluid pressure at inlet 203. As the fluid pressure increases sufficiently to overcome poppet spring 247, fluid first flows around and through poppet 246, through the apertures 226 in inverted cup 225, and finally to exit fluid outlet 204 as suggested by the fluid flow arrows in Figure 16. Thus, the embodiment of Figures 13 to 16 provides a configuration where the inlet and outlet are in closer physical proximity and the dosing volume control knob is more distant from the inlet and outlet portions of the DVCD device.

Figure 17 illustrates another embodiment of the DVCD which has particular application (although not exclusive application) in conjunction with diaphragm pumps. As used herein, a “diaphragm pump” generally refers to a positive displacement pump that uses a combination of the reciprocating action of a flexible (e.g., rubber, thermoplastic or teflon) diaphragm and suitable valves on either side of the diaphragm (check valve, butterfly valves, flap valves, or any other form of shut-off valves) to pump a fluid. Figure 17 shows a driver 100 such as described above (e.g., US Patent No. 8,087,345) which supplies reciprocating motion to the plunger 325 of DVCD 1. The diaphragm pump 350 is connected to DVCD 1 (typically by bolts not shown in the Figures) on the opposite side of driver 100. It will be

understood that driver 100 and diaphragm pump 350 are illustrated primarily to demonstrate one operating environment in which this DVCD embodiment may be employed and this embodiment of the DVCD is not limited to a particular driver type or a particular pump type. For example, electrically powered drivers or internal combustion drivers could alternatively be employed.

Figure 18 demonstrates in greater detail the main components of this embodiment of DVCD 1. The DVCD will generally comprise the housing 302 having the accumulator chamber 305 formed therein. Positioned within accumulator chamber 305 is the accumulator 310, which in this embodiment, has the spring cavity 311 and the tapered nose portion 312 engaging a similarly tapered surface at one end of accumulator chamber 305. The adjustable stop 315 also engages accumulator chamber 305. This embodiment of adjustable stop 315 includes knob portion 316, stem 317, and stop surface 318. The stop surface 318 takes the form of an inverted cup defining a spring cavity 319 and having perimeter surface which is configured to engage (i.e., has a similar surface as) the corresponding perimeter surface on accumulator 310. Naturally, the inverted cup is merely one example of the stop surface shape and alternate embodiments of stop surface 318 could take any number of different shapes. A biasing mechanism 324 acts to bias accumulator 310 away from stop surface 318. In the example of Figure 18, the biasing mechanism is a conventional spring, but could be any other conventional or future developed biasing device.

In the illustrated embodiment, stem 317 of adjustable stop 315 does not directly engage the walls of accumulator chamber 305, but rather the external threads of a threaded bushing 322 engage the walls of accumulator chamber 305 and internal threads on bushing 322 engage external threads on stem 317. It can readily be recognized that this arrangement allows rotation of knob 316 to move stop surface 318 toward and away from accumulator 310, thereby allowing stop surface 318 to limit the range of movement of accumulator 310. It will be understood that adjustable stop 315 is only one manner of adjusting the potential travel distance of accumulator 310 and other conventional or future developed techniques could be employed. As one nonlimiting example, the cam system seen in Figure 5 could be employed in place of the adjustable stop seen in Figures 17-19.

DVCD 1 further comprises a reservoir housing 303 which forms a reservoir space 306 for containing the drive fluid which will drive the diaphragm in diaphragm pump 350. The drive fluid could be any number of fluids which will operate the DVCD and pump 350 as described herein, but one acceptable drive fluid is a conventional gear oil such as 15-30W. A

vent cap 307 engages reservoir housing 303 and allows the internal volume of the reservoir to be maintained at the pressure (typically atmospheric) of the external environment. It can also be seen that an inlet passage 335 communicates with reservoir space 306, accumulator chamber 305, and the distribution passage 336, which in turn interfaces with hydraulic pump 350. It is understood that fluid flow through these passages is “drive fluid”, which drives the diaphragm. The fluid intended to be moved by pump (the “pumped fluid”) is isolated on the opposite side of the diaphragm and passes through an opposing pair of check valves (not shown in drawings).

Figure 18 also illustrates how the plunger 325 extends through reservoir space 306 and into inlet passage 335. The illustrated embodiment of plunger 325 further includes the internal passage 326 which is open at the end of plunger 325 (i.e., is in fluid communication with inlet passage 335) and one or more side bores or “sippy holes” 327 that extend through plunger 325 and are in fluid communication with internal passage 326. It will be understood that fluid under pressure in inlet passage 335 is acting on the nose of accumulator 310 and via distribution passage 336 and apertures in strainer plate 351, on diaphragm 352. Pressurized fluid in inlet passage 335 will also act on bleed screw 330 through bleed passage 337. In this embodiment, bleed screw 330 is a manually operated poppet or ball type bleed screw, which is intended bleed any air from the system in preparation for normal operation. Another passage seen in Figure 18 is bypass path 304 which extends between accumulator chamber 305 and reservoir space 306, allowing any fluid which escapes above accumulator 310 to return to reservoir space 306.

In operation, the plunger will reciprocate between two positions, the top dead position and the bottom dead position. The top dead position refers to the end of the suction stroke as suggested in Figure 18 and the bottom dead position refers to the end of the discharge stroke as seen in Figure 19. Figure 17 illustrates plunger 325 at the end of the suction stroke, with the main drive piston 109 of drive 100 is in its raised positioned. As seen in in Figure 18, this positions the end of plunger 325 within inlet passage 335, but the sippy hole 327 outside of inlet passage 335 and in fluid communication with reservoir space 306. In this position, drive fluid equalizes through sippy holes 327, internal passage 326, and fills inlet passage 335 due to hydrostatic pressure along with a slight negative acting pressure resulting from the void created when any extra fluid squeezes between plunger and the inlet passage 335 and out through the sippy holes 327 once they clear the inlet passage entrance and make their way into the ambient condition reservoir. In the discharge stroke, drive piston 109 moves plunger

325 forward into inlet passage 335 as suggested in Figure 19. After sippy holes 327 move into inlet passage 335, the close tolerances with the inlet passage walls substantially inhibit fluid in inlet passage 335 from escaping back into reservoir 306. Thus, pressure on the fluid in inlet passage 335 increases. Similar to other embodiments described above, the accumulator 310 is able to move up against the force of spring 324 if fluid pressure is sufficiently high. Therefore, a certain volume of fluid may be directed into accumulator chamber 305, thereby reducing the pressure that would otherwise act on diaphragm 352 and the displacement that diaphragm 352 would undergo. Naturally, the pressure acting on diaphragm 352 and its displacement affect the pressure and volume of pumped fluid moving through diaphragm pump 350. Therefore, to the degree which accumulator 310 can move upward, less pumped fluid that will be moved by diaphragm pump 350. Obviously, if adjustable stop 315 is screwed all the way down until stop 315 presses accumulator 310 against the bottom of the accumulator chamber 305, then no fluid is diverted into the accumulator chamber during the discharge stroke. As plunger 325 withdraws in the next suction stroke, spring 324 acts to return accumulator 310 to its fully seated position in accumulator chamber 305 as seen in Figure 18.

In the illustrated embodiment, accumulator 310 rests within accumulator cavity 305 with sufficiently close tolerances that a hydraulic ram seal effect is achieved. However, other sealing techniques could be used in the alternative, nonlimiting examples of which are mechanical seals (e.g., o-rings) and labyrinth seals. As described above, any fluid escaping above accumulator 310 may ultimately be returned to reservoir space 306 via bypass path 304. It will be understood that in many embodiments, it will be relatively fine adjustments of accumulator 310 which affect the amount of fluid acting against diaphragm 352. For example, in one embodiment, the volume of fluid allowed into accumulator chamber 305 is between about 1 ml and about 100 ml. Obviously in other embodiments, the volume of fluid allowed in accumulator chamber 305 could be much greater or even smaller than this range.

As suggested by Figure 17, this embodiment of the DVCD/pump system may be visualized as separated into three discrete and separable sections which are bolted (or otherwise connected together). Thus, the pump forms a first separable section A, the accumulator chamber is formed in a second separable section B, and the reservoir housing is formed in a third separable section C. Naturally, other embodiments could be formed of fewer or more separable sections.

Figures 20 and 21 illustrate a slight variation from the embodiments of Figures 17 to 19. Figure 20 is an end view of a DVCD/pump combination showing the section line for the cut-away view in Figure 21. In this embodiment, the plunger 325 is solid as seen in Figure 21, i.e., it does not have an internal passage 326 or sippy holes 327. However, this embodiment further includes a one-way valve (e.g., a check valve) 340 positioned to interface with reservoir space 303 and deliver fluid to diaphragm 352 via relief passage 341, i.e., the flow direction through the one-way valve is from the reservoir space 303 toward the diaphragm 352. This embodiment operates in a similar manner to that of Figures 17-19, except that it does not rely on sippy holes for replenishing fluid to the inlet passage during the suction stroke. Rather, as plunger 325 moves away from diaphragm 352 during the suction stroke, any tendency to create a vacuum in inlet passage 335 is relieved by the ability of fluid to flow from reservoir space 303, through one-way valve 340 and relief passage 341, to and around diaphragm 352, and eventually to inlet passage 335 (presuming that volume of fluid flow is necessary to relieve the vacuum caused by the withdrawing plunger). Of course, sippy holes 327 and one-way valve 340 are merely two example techniques for equalizing pressures across the system during its operation and those skilled in the art will see many other techniques which should also be considered within the scope of the present invention.

Many other embodiments of the invention may be conceptualized by considering the functional components of the DVCD. For example, another embodiment is a DVCD in which a solid component moves in response to pressure exerted by fluid within a positive displacement pump head during its discharge cycle, and is subsequently replaced prior to that pump's replenishment cycle, subtracting thereby a portion of fluid that would otherwise have been discharged. This DVCD may have a solid component which is adjustable. A further DVCD embodiment substitutes for and acts as the discharge check valve of a positive displacement pump, in which a solid component moves as described immediately above, in concert with normal check valve components (e.g., a ball or poppet). In this embodiment, the solid component is also adjustable.

Those skilled in the art will recognize that the described embodiments of DVCD 1 directly control dosing volume without disturbing the mechanical motion of the driver. Instead, DVCD 1 directly varies dosing volume at the point of delivery by controlling the "apparent size" of the dosing chamber. DVCD 1 causes a precisely controlled portion of fluid that would normally be discharged during the discharge portion of the pumping cycle to be "borrowed" immediately before it is delivered, then "paid back" or returned to the dosing

chamber immediately prior to the replenishment or suction portion of the dosing cycle. DVCD 1 allows a controllable solid component to move “in place” of a variable portion of the fluid that would have otherwise been discharged. This solid component moves a controlled distance in response to the hydraulic pressure from the discharge cycle, just prior to fluid discharge, and then resets itself in response to vacuum pressure just prior to the fluid replenishment or suction cycle, returning the displaced volume to the pump. It is entirely passive, merely reacting to the discharge and replenishment cycles, and it involves only one moving part in addition to what would exist in a non-controllable pump. Nevertheless, not all embodiments of DVCD 1 need have the above described functionalities and embodiments lacking such functionalities are also intended to come within the scope of the present invention.

1. A volume control device comprising:
 - a. a housing having an inlet passage, an outlet passage, and an internal chamber communicating with the inlet and outlet passages;
 - b. an accumulator movably positioned within the internal chamber and substantially conforming with walls of the internal chamber where the accumulator includes an internal passage allowing fluid flow therethrough;
 - c. an one-way valve positioned in the internal passage of the accumulator where the valve is biased in a closed position;
 - d. an adjustable seat positioned within the housing internal chamber between the accumulator and the housing outlet passage;
 - e. a positioning mechanism engaging the housing and adjustable seat whereby the position of the adjustable seat within the housing internal chamber may be adjustably fixed.
2. The volume control device of claim 1, wherein the accumulator seals against a lower portion of the internal chamber and the internal passage of the accumulator is substantially aligned with the inlet passage of the housing.
3. The volume control device of claim 1, wherein the valve within the accumulator is a poppet type with a spring biasing it in the closed position.
4. The volume control device of claim 1, wherein a first position of the adjustable seat holds the accumulator against a lower portion of the housing internal chamber.
5. The volume control device of claim 4, wherein a second position of the adjustable seat allows the accumulator to traverse a first distance within the housing internal chamber.
6. The volume control device of claim 5, wherein a third position of the adjustable seat allows the accumulator to traverse a second, greater distance within the housing internal chamber.
7. The volume control device of claim 1, wherein the positioning mechanism comprises at least one cam member rotating within the housing internal chamber.
8. The volume control device of claim 6, wherein the accumulator is free to travel the first or second distance subject only to seal friction between the accumulator and wall of the housing internal chamber.
9. The volume control device of claim 7, wherein the positioning mechanism comprises two cam members engaging cam pins on the adjustable seat.
10. The volume control device of claim 1, further comprising a first seal positioned between the accumulator and a wall of the housing internal chamber and a second seal positioned between the adjustable seat and the wall of the housing internal chamber.

11. The volume control device of claim 1, wherein the positioning mechanism includes a control surface external to the housing.
12. The volume control device of claim 11, wherein the positioning mechanism includes a bolt member and the control surface is a gripping surface on one end of the bolt member.
13. The volume control device of claim 1, wherein the one way valve allows flow in the direction of the inlet passage toward the outlet passage.
14. The volume control device of claim 1, wherein the positioning mechanism comprises mating threaded surfaces on a portion of the wall of the housing internal chamber and on the adjustable seat.
15. The volume control device of claim 14, wherein the adjustable seat includes a threaded stem in-line with the inlet passage.
16. The volume control device of claim 1, wherein the accumulator has a larger first end and a smaller second end, and said smaller second end slides into an aperture in the adjustable seat.
17. The volume control device of claim 16, wherein the second end slides freely within the adjustable seat.
18. The volume control device of claim 1, wherein components positioned within the housing consist essentially of the accumulator, the adjustable seat, and the positioning mechanism.
19. The volume control device of claim 1, wherein the positioning mechanism comprises a means for altering the position of the adjustable seat within the housing in order to allow a different degree of travel within the housing by the accumulator.
20. A reciprocating pump system with adjustable volume control, the system comprising:
 - a. a reciprocating pump having a fluid inlet allowing fluid to enter the pump during an intake cycle and a fluid outlet allowing fluid to exit the pump during a discharge cycle; and
 - b. a volume control device in fluid communication with the pump outlet, the control device comprising:
 - i. a housing having an inlet passage communicating with the pump outlet, an outlet passage, and an internal chamber communicating with the inlet and outlet passages;
 - ii. an accumulator movably positioned within the internal chamber and have at least one surface substantially conforming with walls of the internal chamber where the accumulator includes an internal passage allowing fluid flow therethrough;
 - iii. a valve positioned in the internal passage of the accumulator where the valve is biased in a closed position;

- iv. an adjustable seat positioned within the housing internal chamber;
- v. a positioning mechanism engaging the housing and adjustable seat whereby the position of the adjustable seat within the housing internal chamber may be adjustably fixed.

21. A volume control device comprising:

- a. a housing having an inlet passage, an outlet passage, and an internal chamber communicating with the inlet and outlet passages;
- b. a volume control means for controlling a volume of fluid within the internal chamber, the volume control means further including an internal passage allowing fluid flow therethrough;
- c. a flow direction control means for allowing one-way fluid flow, the flow direction control means being positioned in the internal passage of the volume control means and being biased in a closed position;
- d. a seating means for adjustably positioning the volume control means within the housing internal chamber, the seating means being between the volume control means and the housing outlet passage;
- e. a positioning means for adjustably fixing the position of the seating means within the housing internal chamber.

22. A volume control device comprising:

- a. an inlet passage and an outlet passage;
- b. an accumulator positioned in an accumulator chamber wherein the accumulator chamber is in fluid communication with the inlet passage;
- c. a positioning mechanism whereby the position of the accumulator in the accumulator chamber may be adjustably fixed;
- d. an one-way valve positioned in an one-way valve chamber wherein the one-way valve chamber is in fluid communication with the inlet passage; and
- e. wherein the one-way valve chamber is in fluid communication with the outlet passage and the one-way valve is biased in a position closing off the inlet passage from the outlet passage.

23. The volume control device of claim 22, wherein an accumulator passage provides a fluid connection between the outlet passage and the accumulator chamber.

24. The volume control device of claim 22, wherein an adjustable seat holds the accumulator against one end of the accumulator chamber.

25. The volume control device of claim 24, wherein a first position of the adjustable seat allows the accumulator to traverse a first distance within the accumulator chamber and

second position of the adjustable seat allows the accumulator to traverse a second distance within the accumulator chamber.

26. The volume control device of claim 22, wherein the one-way valve is a poppet type with a spring biasing it in the closed position.

27. The volume control device of claim 22, further comprising a first seal positioned between the accumulator and a wall of the accumulator chamber.

28. The volume control device of claim 22, wherein the one-way valve allows flow in the direction of the inlet passage toward the outlet passage.

29. The volume control device of claim 24, wherein the positioning mechanism comprises mating threaded surfaces on a portion of the wall of the accumulator chamber and on the adjustable seat.

30. The volume control device of claim 22, wherein the accumulator chamber, the one-way valve chamber, the inlet passage, and the outlet passage are formed in a single unitary housing.

31. The volume control device of claim 22, wherein the accumulator chamber and the one-way valve chamber are formed in separate bodies and external conduits connect the inlet passage and the outlet passage to the accumulator chamber and the one-way valve chamber.

32. The volume control device of claim 1, wherein the accumulator substantially conforming with walls of the internal chamber includes a seal positioned between the walls and the accumulator.

33. A volume control device comprising:

- a. a housing having an inlet passage;
- b. an accumulator positioned in an accumulator chamber wherein the accumulator chamber is in fluid communication with the inlet passage; and
- c. a positioning mechanism whereby the travel of the accumulator in the accumulator chamber may be adjusted.

34. The volume control device of claim 33, wherein the positioning mechanism includes a stop surface configured to engage the accumulator.

35. The volume control device of claim 34, wherein the positioning mechanism includes a threaded stem attached to the stop surface and allowing adjustment of the stop surface toward and away from the accumulator.

36. The volume control device of claim 34, wherein a biasing mechanism is positioned between the accumulator and the stop surface.

37. The volume control device of claim 33, wherein the inlet passage communicates with a fluid reservoir containing a drive fluid.
38. The volume control device of claim 37, wherein a plunger communicates with the reservoir and pressurizes drive fluid in the inlet passage.
39. The volume control device of claim 38, wherein the plunger includes an internal passage oriented in an lengthwise direction and a side outlet communicating with the internal passage.
40. The volume control device of claim 39, wherein the operating stroke of the plunger moves the side outlet from within the reservoir to within the inlet passage.
41. The volume control device of claim 37, wherein a bypass fluid path extends from the accumulator chamber to the fluid reservoir.
42. The volume control device of claim 38, wherein a diaphragm pump communicates with the inlet passage and operation of the plunger increases pressure on the drive fluid acting against a diaphragm in the pump.
43. The volume control device of claim 42, wherein the diaphragm pump includes a strainer plate.
44. The volume control device of claim 38, wherein the accumulator moves along a first axis and the plunger moves along a second axis substantially perpendicular to the first axis.
45. The volume control device of claim 33, wherein the accumulator chamber is in the housing.
46. The volume control device of claim 33, wherein an one-way valve positioned in an one-way valve chamber wherein the one-way valve chamber is in fluid communication with the inlet passage.
47. The volume control device of claim 46, wherein the one-way valve chamber is in fluid communication with an outlet passage in the housing and the one-way valve is biased in a position closing off the inlet passage from the outlet passage.
48. The volume control device of claim 47, wherein an accumulator passage provides a fluid connection between the outlet passage and the accumulator chamber.
49. The volume control device of claim 47, wherein an adjustable seat holds the accumulator against one end of the accumulator chamber.
50. The volume control device of claim 49, wherein a first position of the adjustable seat allows the accumulator to traverse a first distance within the accumulator chamber and second position of the adjustable seat allows the accumulator to traverse a second distance within the accumulator chamber.

51. The volume control device of claim 47, wherein the one-way valve is a poppet type with a spring biasing it in the closed position.
52. The volume control device of claim 47, further comprising a first seal positioned between the accumulator and a wall of the accumulator chamber.
53. The volume control device of claim 47, wherein the one-way valve allows flow in the direction of the inlet passage toward the outlet passage.
54. The volume control device of claim 49, wherein the positioning mechanism comprises mating threaded surfaces on a portion of the wall of the accumulator chamber and on the adjustable seat.
55. The volume control device of claim 47, wherein the accumulator chamber, the one-way valve chamber, the inlet passage, and the outlet passage are formed in a single unitary housing.
56. The volume control device of claim 47, wherein the accumulator chamber and the one-way valve chamber are formed in separate bodies and external conduits connect the inlet passage and the outlet passage to the accumulator chamber and the one-way valve chamber.
57. A diaphragm pump system comprising:
- a. a diaphragm pump;
 - b. a volume control device comprising:
 - i. a housing having an inlet passage, the housing being fluidly connect to the diaphragm pump;
 - ii. an accumulator positioned in an accumulator chamber wherein the accumulator chamber is in fluid communication with the inlet passage; and
 - ii. a positioning mechanism whereby the travel of the accumulator in the accumulator chamber may be adjusted.
58. The volume control device of claim 57, wherein the positioning mechanism includes a stop surface configured to engage the accumulator.
59. The volume control device of claim 58, wherein the positioning mechanism includes a threaded stem attached to the stop surface and allowing adjustment of the stop surface toward and away from the accumulator.
60. The volume control device of claim 58, wherein a biasing mechanism is positioned between the accumulator and the stop surface.
61. The volume control device of claim 57, wherein the inlet passage communicates with a fluid reservoir containing a drive fluid.

62. The volume control device of claim 61, wherein a plunger communicates with the reservoir and pressurizes drive fluid in the inlet passage.
63. The volume control device of claim 62, wherein the plunger includes an internal passage oriented in an lengthwise direction and a side outlet communicating with the internal passage.
64. The volume control device of claim 63, wherein a discharge stroke of the plunger moves the side outlet from within the reservoir to within the inlet passage.
65. The volume control device of claim 61, wherein a bypass fluid path extends from the accumulator chamber to the fluid reservoir.
66. The volume control device of claim 62, wherein operation of the plunger increases pressure on the drive fluid acting against a diaphragm in the pump.
67. The volume control device of claim 57, wherein the diaphragm pump includes a strainer plate.
68. The volume control device of claim 62, wherein the accumulator moves along a first axis and the plunger moves along a second axis substantially perpendicular to the first axis.
69. The volume control device of claim 61, wherein the diaphragm pump forms a first separable section, the accumulator cavity is formed in a second separable section, and the fluid reservoir forms a third separable section.
70. The volume control device of claim 69, wherein the inlet passage is formed through the second and third separable sections.
71. A method of adjusting the flow of fluid delivered by a pump comprising the steps of:
- a. connecting a drive fluid inlet of the pump to an outlet of a volume control device, where the volume control device includes;
 - i. a housing having an inlet passage, the housing being fluidly connect to the inlet of the pump;
 - ii. an accumulator positioned in an accumulator chamber wherein the accumulator chamber is in fluid communication with the inlet passage; and
 - ii. a positioning mechanism whereby the travel of the accumulator in the accumulator chamber may be adjusted;
 - b. advancing a plunger within the inlet passage, thereby increasing fluid pressure at the accumulator and the drive fluid inlet of the pump.
72. The method of adjusting fluid of claim 71, wherein the positioning mechanism includes a stop surface configured to engage the accumulator.
73. The method of adjusting fluid of claim 72, wherein a biasing mechanism is positioned between the accumulator and the stop surface.

74. The method of adjusting fluid of claim 72, wherein the inlet passage communicates with a fluid reservoir containing a drive fluid.
75. The method of adjusting fluid of claim 71, wherein the plunger includes an internal passage oriented in an lengthwise direction and a side outlet communicating with the internal passage.
76. The method of adjusting fluid of claim 75, wherein a discharge stroke of the plunger moves the side outlet from within the reservoir to within the inlet passage.
77. The method of adjusting fluid of claim 76, wherein a bypass fluid path extends from the accumulator chamber to the fluid reservoir.
78. The method of adjusting fluid of claim 71, wherein operation of the plunger increases pressure on the drive fluid acting against a diaphragm in the pump.
79. The method of adjusting fluid of claim 71, wherein the accumulator moves along a first axis and the plunger moves along a second axis substantially perpendicular to the first axis.
80. The method of adjusting fluid of claim 74, wherein a one way valve communicates between the reservoir and a diaphragm of the pump, the check valve being oriented to allow flow from the reservoir, past the diaphragm, and toward the inlet passage of the volume control device.
81. The method of adjusting fluid of claim 71, wherein the accumulator moves along a first axis and the plunger moves along a second axis substantially perpendicular to the first axis.